



## Indoor Air Pollution and Lung Cancer in Guangzhou, People's Republic of China

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A case-control study comprising 224 male and 92 female incident lung cancer cases and the same number of individually matched hospital controls was conducted from June 1983 to June 1984 in Guangzhou, People's Republic of China, to evaluate the association between indoor air pollution and lung cancer risk. Guangzhou residents were exposed to several sources of pollution in their homes, most importantly to cooking fumes. Increased risks were found among subjects living in a house without a separate kitchen (the exposure odds ratio was 2.4 (95% confidence interval (CI) 1.4-4.2) for men and 5.9 (95% CI 2.1-16.0) for women). Similarly, living in a house with poor air circulation was associated with an exposure odds ratio of 2.1 (95% CI 1.2-3.8) for men and 3.6 (95% CI 1.4-9.3) for women. A trend in the association between lung cancer risk and factors pertaining to house and kitchen ventilation was observed, and a decreasing risk of lung cancer was observed for several variables indicating better ventilation, even after adjustment for potential confounders such as education, occupation, living area, smoking, and history of chronic respiratory diseases. No statistically significant differences were found between cases and controls for frequency of cooking at home, presence of a chimney in the kitchen, or type of cooking fuel. Smoking was clearly related to risk of lung cancer in both men and women, and among nonsmoking women, exposure to tobacco smoke from their spouses was also associated with an increased risk. These results suggest that, in addition to smoking, indoor air pollution may be a risk factor for lung cancer. *Am J Epidemiol* 1993;137:145-54.

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Lung cancer is the major cause of cancer death for both men and women in Guangzhou, the main city in the Guangdong province of the People's Republic of China, representing about one fourth of all cancer deaths in that city. During the period 1981-1984, the crude mortality rates for lung cancer in the Guangzhou metropolitan area

were, respectively, 45 male deaths and 24 female deaths per 100,000 person-years (1). Although smoking is the most important cause of lung cancer (2-4), smoking behavior cannot fully explain the epidemiology of lung cancer in Chinese women, in whom there is a rather high incidence of lung cancer, predominantly adenocarcinoma, de-

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Abbreviation: CI, confidence interval.

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spite relatively low smoking rates (5-12). The male:female ratio of lung cancer incidence is about 2 in China (1, 13), even though there is a much bigger difference than that in smoking rates between men and women. In contrast, this ratio varies from 4 to 10 in Western Europe and is about 2 in the United States (13), but with a much higher prevalence of current and former smokers among American women.

During the last decade, increasing attention has been paid to the health effects of the indoor microenvironment. Some studies have shown a positive relation of passive smoking to lung cancer risk (14-18), as well as an association with exposure to radon and its decay products (19-25). However, research results for other sources of indoor air pollution, such as cooking and heating, have been rather elusive and inconclusive (26-29). The goal of this study was to evaluate whether there is any relation between indoor air pollution resulting from domestic cooking practices and lung cancer occurrence.

#### MATERIALS AND METHODS

Newly diagnosed cases of primary lung cancer (*International Classification of Diseases*, Ninth Revision, code 162) were selected from eight major hospitals covering most of Guangzhou from June 1983 to June 1984. All cases occurred in permanent residents of the city of Guangzhou. A total of 327 lung cancer cases were identified from the medical records of these eight hospitals during that year. It was possible to complete an interview for 316 cases (224 men and 92 women; 96.6 percent). Eleven cases were excluded because either they were too ill to answer the interview, they could not be traced, or they had already died. Fifty-five percent of cases were diagnosed by means of repeated chest radiographic examinations and clinical examination; 13 percent were diagnosed by bronchoscopy alone; and 32 percent of the cases had cytologic or histologic confirmation.

Controls who were also permanent residents of the city of Guangzhou were individually matched to cases on age (to within 2

years), sex, residential district (Liwan, Yuexiu, Haizhu, or Dongshan), and date of diagnosis or hospital admission. Controls were selected according to the matching criteria among inpatients of the surgery departments at six of the same eight major hospitals. No controls were chosen from either the Tumor Hospital or the Chest Hospital. Patients who had been admitted for chronic obstructive diseases of the lung, pulmonary tuberculosis, malignant tumors, and coronary heart disease were excluded. Each control was to be interviewed during the 2 months following the interview of his/her matched case. In most instances, the first selected patient control was interviewed; only for 26 subjects were second-choice controls chosen because of an inability to trace the subject or because an individual was found to be inadequate regarding one or several of the matching variables. No subject refused the interview.

The interview was carried out at the subject's home by trained epidemiologic workers using a structured questionnaire. All cases and controls were interviewed in person. The interviewers obtained extensive information about the subject's general demographic characteristics, occupational history, history of respiratory diseases, family cancer history, smoking habits, spouse's smoking habits, cooking practices (including domestic fuel use), and residence history. After completing the questionnaire, the interviewer measured the size of the windows and doors that opened onto the outside of the building, thereby providing an estimation of ventilation capacity. The ventilation capacity of the kitchen was analyzed separately from that of the rest of the dwelling, hereafter designated the living area. If the subject had lived in his or her present home for less than 20 years, the interviewer asked similar questions regarding the preceding residences and their ventilation conditions. In the latter case, given that no measurements were available, the ventilation conditions of previous residences were simply ranked as poor, average, or good based on the questionnaire data. Data on up to three residences were collected; however, since the

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population of the People's Republic of China is relatively stable, very few subjects had moved more than twice.

Exposure odds ratios, their 95 percent confidence intervals, and significance levels were computed using a matched-pair analysis method (30). A conditional logistic regression model was used to estimate exposure odds ratios for multiple class variables and to adjust for confounding factors. The SAS (31) and EGRET (32) software packages were used for the analysis.

## RESULTS

Table 1 presents the demographic characteristics of lung cancer cases and controls.

The ages of cases ranged from 28 years to 83 years, but the majority of cases were in their fifties or sixties. The median ages of male and female cases were 62 years and 60.5 years, respectively. The median ages of male and female controls were 62 and 61.5. Almost all subjects were of Han nationality, and most subjects had been born in the province of Guangdong. Marital status, educational level, dialect, occupation, and living area did not differ significantly between cases and controls, although cases had a lower educational level and a smaller average living area than controls. Thus, we controlled for education, occupation, and living area when we analyzed other variables.

TABLE 1. Demographic characteristics of lung cancer cases and controls, Guangzhou, People's Republic of China, 1983-1984

Characteristic	Men				Women			
	No. of cases	%	No. of controls	%	No. of cases	%	No. of controls	%
<b>Age (years)</b>								
<40	2	0.9	3	1.3	1	1.1	1	1.1
40-49	13	5.8	12	5.4	9	9.8	10	10.9
50-59	76	33.9	80	35.7	33	36.9	33	35.9
60-69	90	40.2	84	37.5	24	26.1	23	25.0
≥70	43	19.2	45	20.1	25	27.2	25	27.2
<b>Marital status</b>								
Married	193	86.2	194	86.6	56	60.9	53	57.6
Widowed	27	12.1	24	10.7	36	39.1	33	35.9
Divorced	3	1.3	4	1.8	0	0.0	0	0.0
Single	1	0.4	2	0.9	0	0.0	6	6.5
<b>Years of education</b>								
<1	22	9.8	10	4.5	40	43.5	41	44.6
1-6	139	62.1	134	59.8	35	38.0	35	38.0
7-12	50	22.3	60	26.8	17	18.5	16	17.4
≥13	13	5.8	20	8.9	0	0.0	0	0.0
<b>Province of birth</b>								
Guangdong	207	92.4	206	92.0	80	87.0	83	90.2
Other	17	7.6	18	8.0	12	13.0	9	9.8
<b>Occupation</b>								
Worker	152	67.8	153	68.3	59	64.1	55	59.8
Other	70	31.3	67	29.9	11	12.0	13	14.1
None	2	0.9	4	1.8	22	23.9	24	26.1
<b>Living area (m<sup>2</sup> per person)</b>								
<2.00	11	4.9	6	2.7	2	2.2	2	2.2
2.00-3.99	56	25.0	42	18.7	27	29.3	15	16.3
4.00-7.99	100	44.6	109	48.7	38	41.3	42	45.6
≥8.00	57	25.5	67	29.9	25	27.2	33	35.9

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TABLE 2. History of occupational exposure and personal and familial history of selected diseases among lung cancer cases and controls, Guangzhou, People's Republic of China, 1983-1984

Exposure	Men					Women				
	No. of cases	No. of controls	EOR, <sup>†</sup>	EOR, <sup>‡</sup>	95% CI <sup>§</sup>	No. of cases	No. of controls	EOR, <sup>†</sup>	EOR, <sup>‡</sup>	95% CI
<b>History of occupational exposure</b>										
None <sup>†</sup>	151	184	1.0	1.0		69	78	1.0	1.0	
Dust	20	8	2.6	2.2	0.76-6.2	13	4	4.3	8.8	1.6-46.6
Smoke	23	12	2.1	2.1	0.89-5.1	1	2	0.74	0.57	0.00-73.4
Other	30	20	1.7	1.6	0.72-3.5	9	8	1.5	1.0	0.26-4.2
<b>History of pulmonary tuberculosis</b>										
Not	137	176	1.0	1.0		78	85	1.0	1.0	
Yes	87	48	2.8	2.4	1.3-4.6	14	7	2.2	1.3	0.39-4.3
<b>History of chronic bronchitis</b>										
Not	125	185	1.0	1.0		63	79	1.0	1.0	
Yes	99	39	3.9	3.0	1.6-5.5	29	13	2.6	0.90	0.36-2.4
<b>Family history of cancer</b>										
Not	203	216	1.0	1.0		83	86	1.0	1.0	
Yes	21	8	2.9	0.90	0.62-1.3	9	6	1.5	0.94	0.54-1.6

\* EOR<sub>1</sub>, matched exposure odds ratio; EOR<sub>2</sub>, matched logistic exposure odds ratio, adjusted for education, occupation, living area, and smoking; CI, confidence interval.

<sup>†</sup> Referent.

As expected, the subjects with lung cancer showed increased frequencies of occupational exposure to hazardous working environments, a history of pulmonary tuberculosis, and a history of chronic bronchitis in both sex groups (table 2). When education, occupation, living area, and smoking were controlled for, the associations of lung cancer with the above risk factors were not substantially modified among men, but they were attenuated or even disappeared among women, except for exposure to dust. In contrast, the increased risk of lung cancer associated with a family history of cancer, found in univariate analysis, disappeared for both men and women when we controlled for the same variables. Smoking was strongly related in a dose-response manner to the risk of lung cancer in both men and women (table 3). Ninety-five percent of male cases and 59 percent of female cases had ever smoked, compared with 80 percent and 25 percent of male and female controls, respectively. The exposure odds ratios for lung cancer were 6.3 (95 percent confidence interval [CI] 2.7-15.0) and 4.9 (95 percent CI 2.3-10.4) among male and female smokers, respectively. An increased risk of lung cancer

was also observed among nonsmoking women who lived with a husband who smoked the equivalent of 20 or more cigarettes per day (table 3).

Table 4 presents information on the cooking practices of lung cancer cases and controls. Results showed that women bore the primary burden of cooking in the family. The majority of families cooked three times per day at home, and coal was the basic cooking fuel used. Questions were asked on the type of fuel used during three historical periods (1949-1957, 1958-1976, and 1977 to the present). Since cooking fuel is rationed by the government, there was little variation in fuel usage among families in Guangzhou. Before 1958, most families used wood and charcoal. From 1958 to 1976, they gradually turned to coal, and gas was used only after 1976. Results are presented for the most recent period, which is the only one in which differences between cases and controls could be distinguished. The history of coal use in Guangzhou was usually longer than 20 years, and only in the past 3-5 years had a small proportion of families changed to petroleum gas as a domestic fuel. Very few families used mainly electricity or kerosene

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TABLE 3. Exposure to smoking among lung cancer cases and controls, Guangzhou, People's Republic of China, 1983-1984

Exposure	No. of cases	No. of controls	Exposure Odds Ratio* 95% CI*
Active smoking (cigarette equivalents smoked per day) among men			
Never smokers†	12	44	1.0
1-19	21	93	1.2 0.43-3.5
20-29	97	66	7.1 2.6-19.5
≥30	94	21	21.4 7.1-64.0
$\chi^2$ for trend = 99.6 $p < 0.001$			
Active smoking (cigarette equivalents smoked per day) among women			
Never smokers†	38	69	1.0
1-9	8	10	1.8 0.57-5.9
10-19	16	9	3.5 1.2-9.8
≥20	30	4	17.9 4.0-80.6
$\chi^2$ for trend = 28.0 $p < 0.001$			
Passive smoking among nonsmoking women (cigarette equivalents smoked per day by husband)‡			
Not exposed†	13	32	1.0
1-19	6	21	0.7 0.23-2.2
≥20	19	16	2.9 1.2-7.3
$\chi^2$ for trend = 4.5 $p = 0.034$			

\* EOR, matched logistic exposure odds ratio, adjusted for education, occupation, and living area, comparing never smokers to present and former smokers combined; CI, confidence interval.

† Referent.

‡ Unmatched method was used.

for cooking. In the kitchens of more than 60 percent of families, there was no chimney or other apparatus for extracting fumes. No significant case-control differences were associated with the above variables.

Information on the use of cooking oil was not formally included in our study. In the People's Republic of China, cooking oil is rationed by the government-controlled food and oil company, and in Guangzhou, the main cooking oil used is peanut oil (for a short time it was bean oil). Rapeseed oil was not widely available, and we did not expect to find any differences in the types of oil being used, because all Guangzhou residents are dependent on the same government supply.

Analysis of the effect of ventilation conditions on lung cancer risk was conducted for housing at the time of diagnosis and interview, as well as housing where subjects had lived the longest; finally, data were summarized over all residences. The results of these analyses were similar (data not shown); therefore, this paper presents only the results of the analysis for current ventilation conditions. In addition, the proportions of cases and controls who had moved during the past 10 or 20 years did not differ significantly, and duration of residence in the current housing was similar for cases and controls. For most subjects, the current residence was also the longest residence.

Table 5 shows that after adjustment for education, occupation, occupational exposure, pulmonary tuberculosis history, chronic bronchitis history, family cancer history, amount of smoking per day, and living area, as well as passive smoking (for women only), several variables pertaining to ventilation conditions were strongly associated with lung cancer risk. There was increased risk associated with having a window or door opening from the kitchen directly into the living area or bedroom, and for cooking in the living area or bedroom. For cooking in the living area or bedroom, the exposure odds ratio was 2.4 (95 percent CI 1.4-4.2) for men and 5.9 (95 percent CI 2.1-16.0) for women. Having windows or doors that opened in different directions so that indoor air could circulate also significantly influenced the risk of lung cancer. The relative risk for lung cancer tended to decrease with increasing size of ventilation openings in living areas and kitchens. For the best ventilated living area as compared with the least ventilated, the exposure odds ratio for lung cancer was reduced to only 0.14 (95 percent CI 0.04-0.51) for men and 0.02 (95 percent CI 0.00-0.21) for women. The exposure odds ratios for kitchen ventilation were 0.15 (95 percent CI 0.05-0.44) for men and 0.06 (95 percent CI 0.01-0.32) for women, respectively. The differences were statistically significant. A similar trend was found for the ceiling height throughout the apartment, but no clear trend was seen for the floor on:

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TABLE 4. Cooking practices of lung cancer cases and controls, Guangzhou, People's Republic of China, 1983-1984.

Cooking practice	Men					Women				
	No. of cases	No. of controls	EO <sub>1</sub> *	EO <sub>2</sub> *	95% CI*	No. of cases	No. of controls	EO <sub>1</sub>	EO <sub>2</sub> *	95% CI
<b>Frequency of cooking at home</b>										
Rarely	107	100	1.0	1.0		4	5	1.0		
Occasionally	45	63	0.65	0.52	0.25-1.1	8	8	1.2	1.2	0.17-9.2
Frequently	72	61	1.1	1.1	0.69-1.9	80	79	1.3	1.1	0.19-6.1
<b>Having a chimney in kitchen (years)</b>										
No chimney†	160	147	1.0	1.0		56	54	1.0	1.0	
1-9	33	37	0.80	0.55	0.22-1.6	16	10	1.7	3.6	0.72-17.5
≥10	31	40	0.70	0.80	0.34-1.9	20	28	0.77	1.1	0.40-3.0
<b>Cooking fuel</b>										
Coal	200	193	1.0	1.0		81	79	1.0	1.0	
Gas	14	22	0.59	0.48	0.15-1.6	8	9	0.90	0.90	0.24-3.3
Wood	8	9	0.79	0.57	0.11-3.0	3	4	0.67	0.67	0.04-11.7
Other	2	0				0	0			
<b>No. of meals prepared at home per day</b>										
0-1†	18	26	1.0	1.0		2	3	1.0	1.0	
2	26	33	1.2	0.83	0.27-2.6	7	12	0.67	0.48	0.03-8.8
3	180	165	1.7	1.3	0.50-3.3	83	77	1.5	1.5	0.12-17.7

\* EO<sub>1</sub>, matched exposure odds ratio; EO<sub>2</sub>, matched logistic exposure odds ratio, adjusted for education, occupation, occupational exposure, history of tuberculosis, chronic bronchitis, family history of cancer, smoking, and living area. CI, confidence interval; EO<sub>3</sub>, matched logistic exposure odds ratio, adjusted for passive smoking in addition to all of the variables listed above.

† Referent.

which the subject lived, with the exception of a higher risk for people living on the ground floor as opposed to a higher floor. When we analyzed the effect of floor by district of residence and by sex, we found the higher risk for persons living on the ground floor in three out of four districts for women and in two out of four districts for men (data not shown).

## DISCUSSION

Usually, hospital controls are selected from the same hospitals as the cases, but in this study some of the controls were not chosen from the same hospital as their matched cases because two of the hospitals that were sources of cases were deliberately excluded as sources of controls. We did this to avoid selection of subjects with diseases that could potentially be linked to smoking and/or air pollution. To reduce potential bias in the control selection procedure, we matched cases and controls on district of residence, thereby controlling for the referral

pattern of patients. Most importantly, this matching also controlled for atmospheric air pollution. Results of environmental surveillance were only available at the district level, as were lung cancer mortality rates. One district, Liwan, has the highest levels for all indexes of air pollution (falling dust, benzo(a)pyrene, total suspended particulate matter, sulfur dioxide, nitrogen oxide, and carbon monoxide), whereas the other three districts do not differ from one another appreciably (33). The highest age-standardized (world standard population) lung cancer mortality rates for women are recorded in Liwan at 22.2 deaths per 100,000 woman-years, compared with the lowest rate for the district of Dongshan at 18.3. For men, the highest mortality rate is in Yuexiu at 51.8, versus the lowest rate in Dongshan at 40.9. All of the pairs of cases and controls lived in the same residential district, in an area of about 10 km<sup>2</sup>. They were exposed to approximately similar levels of outdoor air pollution, although variations may have occurred within districts. No data were avail-

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TABLE 5. Ventilation conditions in the homes of lung cancer cases and controls, Guangzhou, People's Republic of China, 1983-1984

Ventilation factor	Men					Women				
	No. of cases	No. of controls	EO <sub>1</sub> *	EO <sub>2</sub> *	95% CI*	No. of cases	No. of controls	EO <sub>1</sub>	EO <sub>2</sub> *	95% CI
<b>Separate kitchen</b>										
Yes†	72	113	1.0	1.0	1.4-4.2	29	52	1.0	1.0	2.1-16.0
No	152	111	2.0	2.4		63	40	3.1	5.9	
<b>Good air circulation</b>										
Yes†	90	120	1.0	1.0	1.2-3.8	38	60	1.0	1.0	
No	134	104	1.7	2.1		54	32	3.0	3.6	1.4-9.3
<b>Size of ventilation openings in living area (m<sup>2</sup> per person)</b>										
0.0-0.4†	47	48	1.0	1.0		16	6	1.0	1.0	
0.5-0.9	86	69	0.53	0.39	0.14-1.1	36	23	0.69	0.36	0.09-1.5
1.0-1.9	38	53	0.33	0.30	0.10-0.91	22	24	0.40	0.25	0.05-1.1
2.0-3.9	22	30	0.33	0.24	0.06-0.90	9	13	0.24	0.14	0.02-0.89
≥4.0	31	24	0.28	0.14	0.04-0.51	9	26	0.11	0.02	0.00-0.21
x <sup>2</sup> for trend										18.0 (p < 0.001)
<b>Size of ventilation openings in kitchen (m<sup>2</sup> per family)</b>										
0.0-0.4†	79	41	1.0	1.0		22	8	1.0	1.0	
0.5-0.9	58	52	0.55	0.77	0.36-1.7	27	25	0.29	0.11	0.02-0.60
1.0-1.4	48	59	0.38	0.23	0.10-0.56	24	22	0.31	0.13	0.02-0.74
1.5-1.9	19	31	0.28	0.49	0.16-1.5	7	13	0.15	0.09	0.01-0.63
≥2.0	20	41	0.20	0.15	0.05-0.44	12	24	0.16	0.06	0.01-0.32
x <sup>2</sup> for trend										10.3 (p < 0.001)
<b>Height of room (m)</b>										
<2.8†	61	45	1.0	1.0		22	12	1.0	1.0	
2.8-3.1	72	71	0.77	0.91	0.41-2.0	30	26	0.62	0.54	0.09-1.3
≥3.2	91	108	0.65	0.64	0.31-1.3	40	54	0.39	0.23	0.06-0.84
x <sup>2</sup> for trend										5.5 (p = 0.02)
<b>Floor of apartment</b>										
Ground†	106	92	1.0	1.0		50	32	1.0	1.0	
1	77	78	0.85	0.79	0.40-1.5	23	34	0.30	0.12	0.03-0.46
2-3	27	34	0.66	0.88	0.36-2.1	14	22	0.29	0.11	0.02-0.54
≥4	14	20	0.59	0.62	0.20-1.9	5	4	0.56	0.72	0.07-7.01
x <sup>2</sup> for trend										5.0 (p = 0.02)

\* EO<sub>1</sub>, matched exposure odds ratio; EO<sub>2</sub>, matched logistic exposure odds ratio, adjusted for education, occupation, occupational exposure, history of tuberculosis, chronic bronchitis, family history of cancer, smoking, and living area; CI, confidence interval; EO<sub>3</sub>, matched logistic exposure odds ratio, adjusted for passive smoking in addition to all of the variables listed above.

† Referent.

able on a scale smaller than the district. We knew that separation of the effects of outdoor air pollution from those of indoor air pollution might be difficult. This led us to match on residence as a proxy for matching on outdoor air pollution level. In addition, our results, demonstrating a clear reduction in risk of lung cancer for living in a house with large openings onto the outside, indicate that outdoor air pollution is unlikely to

explain or confound the association found between lung cancer risk and indoor sources of air pollution.

Our results showed that comparability between cases and controls with regard to basic demographic variables was good, suggesting that these demographic variables might not have a major confounding effect. Furthermore, education and occupation, which were considered good representative vari-

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ables of social class, were also controlled for in the analysis.

Since the number of cases in each histologic category was limited, a separate analysis could not be carried out for the association of indoor air pollution with specific histologic types of lung cancer. Some diagnostic error may also have occurred. However, undifferential misclassification of cases and controls usually leads only to a bias toward the null and cannot explain the observed results.

It is possible that some social class differences between cases and controls could account for part of the difference in ventilation conditions. The finding of a higher risk of lung cancer among subjects living at street level could be explained by a higher concentration of both indoor and outdoor air pollutants on the ground floor as opposed to higher floors, where natural ventilation is usually better. Social class, which is closely linked with housing conditions in China, was nevertheless more strongly associated with the total surface of the living area than was the specific measure of ventilation. Although cases had smaller living areas than controls, the difference was not substantial. After adjustment for education, occupation, and living area, the relation between ventilation conditions and lung cancer risk remained. This means that any bias linked to social status cannot be a major confounder of the observed association. Recall bias can affect most retrospective studies; however, in this study, the size of ventilation openings was objectively measured, so the association between ventilation conditions and lung cancer risk cannot be an artifact of recall bias.

Smoking was the major cause of lung cancer in both sex groups, and a clear dose-response relation was observed between the amount of tobacco smoked and lung cancer risk. High smoking rates were observed in both male and female groups. These rates were higher than those obtained from a case-control study of lung cancer carried out among Shanghai Chinese women (11) but similar to rates from other studies (6, 10, 18, 34). The subjects of this study belonged to

an older population and had relatively low social status (a low educational level and the major occupation of worker). These two factors are known to be associated with high smoking rates (35). Furthermore, the definition of a smoker in this study included both ever and current smokers. For instance, if we had counted only current smokers, the smoking rate would have been reduced to 14 percent in female controls. Passive smoking may also account for some excess risk, although increased risk was only observed in the women living with husbands who smoked heavily. No effect was seen for women married to light smokers. This may be explained by the reduced sample size and by the imprecise quantification of passive smoking. The results of other studies in Chinese women have suggested that passive smoking contributes to a slight increase in lung cancer risk (11, 18).

Several reports of environmental monitoring showed that the concentrations of nitrogen oxide, sulfur dioxide, benzo(a)pyrene, and total suspended particulate matter in Guangzhou were higher in dwellings than in the outdoor atmosphere and varied according to time of day and season (36). Three peaks of pollutant concentrations during the day were correlated with cooking activities. Results of studies also showed that there were higher concentrations of suspended dust and suspended benzo(a)pyrene in the rooms and urinary benzo(a)pyrene in housewives in households where coal was used as a cooking fuel compared with households where petroleum gas was used (36, 37). Results of a study conducted in the north of China showed that use of coal for heating elevated the risk of lung cancer in comparison with use of gas. Cooking in the bedroom was also related to an excess risk (34). High mortality from female lung cancer in Xuan Wei County, Yunnan Province, was also associated with the combustion of smoky coal at home (38). These results indicated that home cooking practices were a major source of indoor air pollutants and that coal produced more severe air pollution than other kinds of domestic fuel.

Evidence also comes from the evaluation

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of occupational exposure to coal burning. Steel, gas, and coke oven workers have an elevated risk of lung cancer (39-45). The results of animal experiments have demonstrated that some components of coal fumes are carcinogenic or mutagenic (38, 46, 47). Since coal use, frequent home cooking, and lack of an apparatus for extracting fumes are universal in Guangzhou, it was difficult to find a significant difference between any population groups. However, this indicates that severe indoor air pollution exists for most families in Guangzhou, where people live in comparatively overcrowded conditions with poor ventilation. Better ventilation of houses could thus play a key role in improvement of the indoor microenvironment, and dissimilar ventilation conditions could be responsible for different exposure levels of lung cancer cases and controls. During the study period, there was in most houses no artificial ventilation such as air conditioning, so the indoor microenvironmental conditions depended mainly on natural ventilation. The area of ventilation (as defined by the area of openings to the outside) was a good representative measure of ventilation conditions. This is in agreement with other studies on indoor air pollution showing that the concentrations of pollutants are greatly affected by ventilation (19, 34).

In summary, the results of this study suggest that indoor air pollution produced during home cooking is a risk factor for lung cancer in Guangzhou, especially for women, who are more likely to be exposed to coal fumes and cooking oil vapors in the kitchen. This could contribute to the high rate of lung cancer in Chinese women. Further investigations are needed to clarify the precise nature of indoor air pollutants and their carcinogenic mechanisms. It would also be informative to conduct studies by major histologic type, particularly in Chinese women, among whom adenocarcinoma is unusually frequent. Finally, this study was not designed to evaluate the effect of outdoor air pollution; that must be left to future research. In the meantime, our data indicate that in Guangzhou, there are sources of in-

door air pollution which play a role in the occurrence of lung cancer independently of active smoking and outdoor air pollution.

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